Journal of Science Education and Practice *p-ISSN 2548-950X*
Volume 5 Nomor 2 Tahun 2021 *e-ISSN 2549-7170*

Problem-Based Learning with Science, Technology, Engineering, and Mathematics (Stem) Approach to Improve Critical Thinking Skills and Conceptual Understanding of Junior High School Students

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Abstract: This research has done to examine the application of learning with PBL STEM model implemented in one of State Junior High School in Bogor. The method used in this research was quasi experiment with pre-post control design. The experimental class was treated with PBL STEM model, while the control class with PBL model 5M. The subjects involved were 76 students of Junior High School in one of Bogor City, divided into 38 students in experimental class & 38 students in control class. Data collection techniques conducted in this study through observation, tests, and questionnaires. Data analysis was performed using quantitative data analysis and qualitative data analysis. The research shows the increasing of student's critical thinking skill high category (N-Gain value is 70.78%). The Implementation of PBL STEM could improve the concept gaining with the N-Gain value is as much as 69.56%. So, it can be concluded that problem-based learning with STEM approach is appropriate to be implemented in junior high school students of class VIII. In addition, students' responses showed positive results can be seen from the increased interest, liveliness, motivation, in studying the field of STEM.

Keywords: *PBL STEM, critical thinking skills, conceptual understanding.*

INTRODUCTION

Knowledge of science and technology can be provided early on especially in schools. Natural science as one of the subjects mastered in schools is a gateway in developing technology and science. In accordance with the Permendiknas RI Number 22 of 2006 concerning content standards for primary and secondary education units, science subjects in junior high schools / MTs aim to make students have the ability to develop an understanding of various kinds of natural symptoms, concepts and principles of science that are useful and can be applied in everyday life; develop curiosity, a positive attitude, and awareness of the existence of mutually influencing relationships between science, the environment, technology, and society; conducting scientific inquiry to cultivate the ability to think, behave and act scientifically; communicate and improve knowledge, concepts, and skills of science as a basis for continuing education to the next level.

At the junior high school level, the scope of the subject groups of science and technology, is intended to acquire the basic competencies of science and technology and cultivate scientific thinking critically, creatively, and independently. Although the goal is ideal, the reality is that science learning in schools is still not optimal. Another weakness of science learning today is that learning should be student centered, in reality there are still many teachers centered. The implementation of science learning is also still a lot that has not been associated with real life and technological developments in everyday life.

These things affect students' mastery of concepts in learning science, while concept knowledge is very important to be improved in science learning as an effort to understand the natural phenomena above. Concepts are the basis for higher mental processes for formulating principles and generalizations (Dahar, 2011). To solve a problem, a student must know the rules that are relevant and based on the concepts they acquired.

In accordance with the educational objectives above, science learning is also expected to foster students' thinking skills. Ennis in his book (1985) states critical thinking is reasonable reflective thinking, focused on deciding what to believe or do. Eggen (2012) defines critical thinking as the ability and tendency to make assessments of conclusions based on evidence. However, in practice, based on data from student learning evaluation results, it shows that 40% of students' mastery of concepts is still low or below the minimum completion criteria (KKM = 72) and 47.7% of students whose critical thinking skills are still in the low category. In addition, the results of observations made by researchers on students through questionnaires distributed to 70 respondents showed that almost half of respondents (48.57%) did not understand the material studied, 80% of respondents stated that they had difficulty in mathematical calculations. Although students experienced difficulties, 77.14% of respondents stated that they enjoyed practicum activities and had an interest in learning technology (78.57%) and design (82.86%).

From the description above, innovation in learning is needed through innovative learning models and approaches that can encourage increased mastery of concepts and foster students' critical thinking skills. One model that can be used is Problem Based Learning using the Science, Technology, Engineering and Mathematics approach. According to Arends (1997), problem-based learning is learning where students work on authentic problems with the intention of compiling their own knowledge, developing higher-level inquiry, and thinking skills, developing independence, and self-confidence. To benefit from PBL, especially for students of varying levels of thinking ability, special approaches are needed to develop these skills. One of them is the Science, Technology, Engineering, and Mathematics (STEM) approach.

STEM learning is intended to study Science, Technology, Engineering, and Mathematics in one unit in the classroom. This is because most of the latest and most valuable knowledge today involves more than one subject (Moore, 2012). In this approach, the importance of collaboration in the learning process for children is needed. There is a difference between cooperation and collaboration. Collaboration usually results in a synthesis of ideas. When cooperation allows children to achieve goals, collaboration will help them become creative thinkers and problem implementers who understand their own strengths and how to value the strengths of others (Yuen et al, 2014). In addition, it is necessary to facilitate teachers of students who are involved in real-world content

Some of the benefits of STEM education include motivating students to pursue careers in STEM fields and increasing their interest and performance in math and science (Moore, 2012). STEM education also influences some students' perceptions of engineering as a career choice for them (Reynolds et al, 2013). For teachers themselves, the STEM approach makes teachers need to increase knowledge in understanding the fields of engineering, mathematical processes, and statistics for the professional development of their teaching (Reynolds et al, 2013). Stem approaches benefit low-achieving students from improving their achievement to higher and lowering the achievement gap (Han et al, 2014)

STEM-based learning has not been widely practiced in schools. It is therefore very interesting to develop and implement a STEM approach packaged in the PBL model for science learning. In this study, STEM learning with the PBL model was implemented in the Energy material given in class VIII. This material has a direct relationship between science and mathematics (formulas), technology, and engineering (designing simple tools that use the concept of Energy).

Based on literacy studies and the results of learning observations in the classroom, several learning-related problems were found as follows: 1) Low mastery of concepts and critical thinking skills of students. 2) Weak quality of science learning in schools. 3) There are not many teachers who associate science learning with technology and engineering. These three problems have been found solutions through this study. The formulation of the problem raised is "can a problem-based learning model with a STEM approach improve students' critical thinking skills and mastery of concepts?". For this research to be more directed, the formulation of the problem above is detailed into the following research questions: 1) How is the implementation of the problem-based learning model with a STEM approach in improving students' critical thinking skills and mastery of concepts? 2) How does it improve students' critical thinking skills on Energy material and its changes after using problem-based learning models with a STEM approach? 3)

How to improve students' mastery of concepts on Energy material and its changes after using problem-based learning models with a STEM approach? 4) How do students and teachers respond after implementing a problem-based learning model with a STEM approach to Energy material?

METHODS

The research method used in this study is quasi-experimental research. The research design used is a Pre-post test control group design. with the design pattern as shown in table 1.

Table 1 Pre-post control group design pattern

Class	Pretest	Treatment	Postest
Experiment	O_1	X	O_2
Control	O_1	C	O_2

Information:
O1: Critical thinking skills and mastery of learners' concepts before treatment
O2 : Critical thinking skills and mastery of students' concepts after treatment
X: Pembelajaran PBL-STEM
C: PBL-5M Learning

The treatment given to the control class and the experimental class was carried out in three meetings. In the science learning control class using the PBL model with a Saintific (5M) approach, with the stages of observing, questioning, collecting data, associating, and communicating, while the experimental class uses PBL-STEM learning. The samples in this study were students in junior high school grade 8.8 which totaled 38 people as a control class and students in grade 8.9 who totaled 38 people as an experimental class. So that there are a total of 76 students. The procedure in this study consists of 3 stages, namely:

1. **Preparatory Stage**

The steps taken in the preparatory stage include: (1) Carrying out pre-research. (2) Formulate problems from the results of pre-research (3) Preparation of research, which are in the form of: (a) Making research instruments in the form of test grids, tests in the form of essays, answer keys and scoring guidelines, (b) Making learning tools in the form of Learning Implementation Plans and Student Worksheets, (c) Validating research instruments and learning tools in the form of Learning Implementation Plans and Student Worksheets, (d) Revising research instruments based on validation results, (e) Conducting trials of research instruments on learners outside the research sample, (f) Calculating the level of reliability of the test.

2. **Research Implementation Phase**

The implementation of the research includes: (1) Providing pretests in control classes and experimental classes to see students' initial abilities, (2) Providing treatment with science learning with the PBL model in the control class and the PBL-STEM model on the experimental class, (3) Providing posttests in the control class and experimental class with the aim of knowing students' critical thinking skills and mastery of concepts.

3. Final Stage

The final stage of this study includes: (1) Analyzing and processing research data in control classes and experimental classes using relevant statistical tests, (2) Compiling research reports.

Data Collection Techniques

To obtain the expected data, in a study, data collection techniques are needed. This step is very important because the data collected later will be used in testing the hypothesis. In carrying out data collection techniques, it must be adjusted to the required data. In this study, the data collection techniques used are shown in table 2.

Table 2 Data collection techniques

No	Collected data	Data collection techniques
1	Implementation of Learning	Observations, video documentation and photos of activities
2	Critical thinking skills	Essay Tests
3	Mastery of the concept	Multiple choice tests
4	Student responses	Questionnaire

Data Analysis Techniques

Based on data collection techniques, the data obtained in this study is in the form of quantitative data and qualitative data. Quantitative data are obtained from the results of critical thinking skills tests and student concept mastery tests, while qualitative data are obtained from the results of observations of teacher activities and questionnaires of student responses to the learning process which are analyzed descriptively.

1. Quantitative data analysis

Data processing steps by giving a score to each item about the results of pretests and postes. The scoring is in accordance with the answer keys and guidelines used in this study.

2. N-Gain Calculation

After the data is processed in the form of a score, it is continued by calculating the normalized gain (N-Gain) which aims to determine the quality of improving critical thinking skills and mastery of students' concepts. Calculation of N-Gain can use the equation

$<g> = \frac{\%(S_f)-\%(S_i)}{100-\%(S_i)}$ (Hake, 1999)

With captions (Sf) and (Si) are the average of postes and the average of pretests. After obtaining the gain index value, it can be categorized into criteria in table 3.

Table 3 N-gain index value

Rentang nilai	Kategori
(<g>) ≥ 0,71	Tinggi
0,30 > (<g>) ≥ 0,70	Sedang
(<g>) < 30	Rendah

The analysis of the critical thinking skills test is in the form of a description test of 15 questions, the test is tested on grade 38 students by answering the pretest and posttest. Aspects of critical thinking skills analyzed in this study include Elementary Clarification, Basic support, Infeering, Advanced Clarification, and Strategy and tactic.

Population And Samples

The study population was class VIII students of State Junior High Schools in Bogor Regency in the 2016/2017 academic year of 354 students in 9 classes, namely VIII-1 sampai with VIII-9. The determination of sampel in this study used *a random sampling* technique, namely students in class 8.8 totaling 38 people as a control class and students in class 8.9 who were 38 people as experimental classes. So that there are a total of 76 students.

RESULTS AND DISCUSSION

a) Research Results

1. Learning Implementation

The implementation of learning in this study follows the stages of PBL and the stages of STEM. The implementation of learning can be observed during the learning process. The implementation of this learning is based on the results of observations of teacher activities during the teaching and learning process observed by the observer. The study was conducted for 3 meetings. As for the observation data, in table 4.

Table 4 Implementation of learning (teacher activity)

Observed aspects	Scores					
	Meeting					
	1		2		3	
	Observer 1	Observer 2	Observer 1	Observer 2	Observer 1	Observer 2
Preliminary activities	18	19	20	20	20	20
Core Activities						

Learning Management	29	27	32	29	32	32
Application of the PBL-STEM approach and model						
Orientation to the problem Commitment	3	3	4	4	4	4
Learning organizations Explore	3	3	3	4	4	4
Individual and group investigations Explain	3	3	3	3	4	4
Develop and present artifacts and exhibits Elaborate	3	3	3	3	4	4
Analyze and evaluate the process of overcoming problems Evaluation	3	3	3	4	4	4
Assessment Implementation	10	8	12	10	12	11
Closing activities	18	18	18	19	19	19
Total	90	87	98	96	103	102

A graph of the achievement of learning implementation as shown in figure 1.

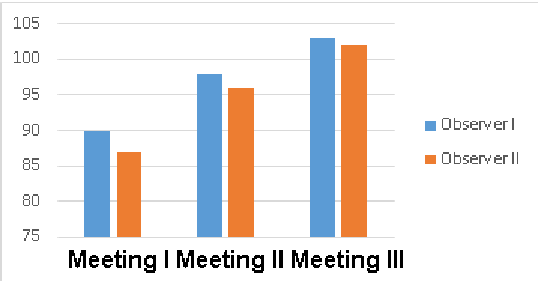


Figure 1 Implementation of teacher activities

2. Mastery of Concepts

Analysis of the concept mastery test in the form of a multiple-choice test of 20 items, the test is tested on grade 38 students by answering *the pretest* and posttest. Aspects of concept mastery based on the cognitive domain of Bloom's taxonomy revisions analyzed in this study include, understanding (C2), applying (C3), analyzing (C4), and evaluating (C5). Data on the results of the processing of pretests, posttests, N-Gains for the mastery of concepts of students of the control class and experimental classes can be seen in appendix D.

p-ISSN 2548-950X
e-ISSN 2549-7170

The percentage comparison of the average scores of pretests, postes, and N – Gains of student mastery of concepts between the experimental class and the control class is shown in Figure 2.

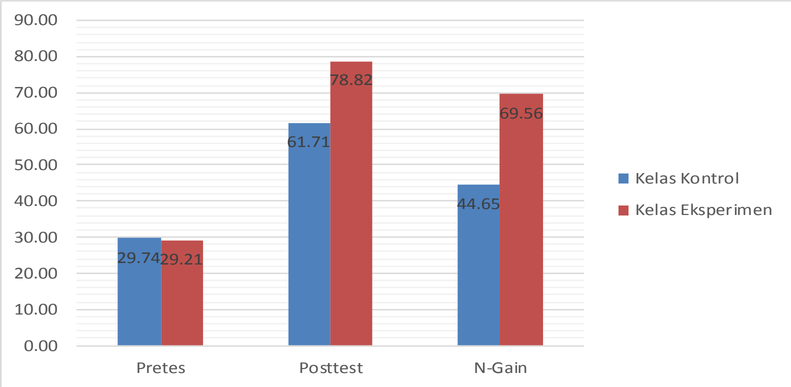


Figure 2 Average scores of pretests, postes, and N-Gain percentages mastery of the concepts of the control class and experimental class.

The percentage increase in the average value of the pretest and posttest is represented by the acquisition of the normalized average gain value (N-Gain). The percentage of the average N-Gain value of the experimental class was 69.56% while the control class was 44.65%. Based on these results, there is an increase in the mastery of the concept of the experimental class higher than that of the control class. The initial data processing and testing steps go through normality tests, homogeneity tests and T tests. Normality test results for experimental classes and control classes as shown in table 5.

Table 5 Normality Test Results Pretest and Postes Value Mastery of Concepts

Data	**Class**	**L_o**	**L_{tabel}**	**Ket**	**Conclusion**
Pretest	Experiment	0.0997	0.1437	H_o Accepted	Normal
	Control	0,1209	0.1437	H_o Accepted	Normal
Postest	experiment	0,1068	0.1437	H_o Accepted	Normal
	Control	0,1264	0.1437	H_o Accepted	Normal

From the results of the normality test data pretest mastery of the concepts of experimental and control classes in table 5. obtained a value of Lo < L_{tabel}, so Ho was accepted. This shows the pretest scores of the mastery of concepts of the students of the experimental class and the normally distributed control class. Similarly, the posttest score where the value of the Lo value < L_{tabel}, so that Ho is received shows the posttest data is normally distributed.

Furthermore, a variance homogeneity test was carried out using the Fisher test. The homogeneity test results of the two groups of pretest and posttest can be seen in table 6.

Table 6 Homogeneity Test Results of Pretest and Postes Value Mastery of Concepts

Data	F_h	F_t	Ket	Conclusion
Pretest	1,205	1,72	H_o Accepted	Homogen
Postest	1,630	1,72	H_o Accepted	Homogen

From the results of the homogeneity test, the mastery of the concept as in table 6 shows that where Fh<Ft then Ho is accepted. This suggests both groups of data are from homogeneous populations. Similarly, the posttest data shows Fh<Ft so that Ho is accepted. It also suggests both groups of data are from homogeneous populations.

Furthermore, to find out the difference between the two classes is carried out with a T test. The results of the T test are shown in table 7.

Table 7 T Test Results pretest and posttest data Mastery of Concepts

Data	t_{hitung}	t_{tabel}	Information
Pretes	0,223	2,000	Ho Accepted
Postest	5,787.	2,000	Ho Rejected

In accordance with the test criteria, namely: H0 is accepted if: - ttabel < count < ttabel. As shown in table 7. for the pretest score is obtained th<ttabel, then Ho is accepted, this indicates the initial ability of the same student. Meanwhile, in the postets, it can be seen that the calculation value > ttabel, ho is rejected, so it can be concluded that there is a difference in mastery of concepts between those given by PBL and STEM, meaning that the mastery of student concepts given the STEM method is better than the mastery of student concepts given the PBL method.

Furthermore, an analysis of the improvement of each indicator of mastery of the concept is carried out. The concept mastery aspects reviewed in this study are based on the cognitive domain of bloom revised taxonomy which consists of understanding (C2), applying (C3), analyzing (C4), and evaluating (C5). Figure 3. indicates the N-Gain value for each level of mastery of the concept.

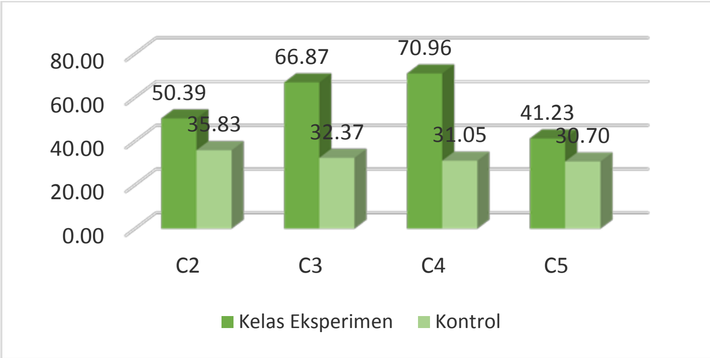


Figure 3 N-Gain for each level of concept mastery

Seen in figure 3. the N-Gain value in the experimental class is higher when compared to the control class. The highest increase in concept mastery in the experimental class was at the C4 level by 70.96% and the control class at the C2 level by 35.83%. Meanwhile, the lowest increase in mastery of concepts in the experimental class lies in the C5 level, namely 41.23% and 30.70% in the control class.

3. Keterampilan Berpikir Kritis

The analysis of the critical thinking skills test is in the form of a description test of 15 questions, the test is tested on grade 38 students by answering the pretest and posttest. Aspects of critical thinking skills analyzed in this study include Elementary Clarification, Basic support, Infeering, Advanced Clarification, and Strategy and tactic. Data on the results of processing pretests, posttests, N-Gains for critical thinking skills of control class students and experimental classes can be seen in the appendix.

The comparison of the percentage of the average score of pretests, postes, and N – Gains of students' critical thinking skills between the experimental class and the control class is shown in Figure 4.

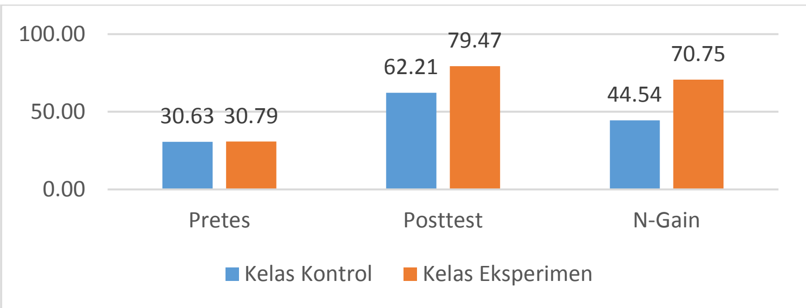


Figure 4 The average score of pretests, postes, and N-Gain critical thinking skills.

The percentage increase in the average value of the pretest and posttest is represented by the acquisition of the normalized average gain value (N-Gain). The percentage of the N-Gain rat-gain value of the experimental class was 70.75% while the control class was 44.54%. Based on these results, it can be seen that there is an increase in critical thinking skills in the experimental class higher than the control class.

Data processing and testing steps for critical thinking skills through normality, homogeneity, and T tests. Preliminary data processing results for experimental classes and control classes as shown in table 8.

Table 8 Results of the pretest normality test and posttest critical thinking skills

Data	**Class**	**L_o**	**L_{tabel}**	**Information**	**Conclusion**
Pretest	experiment	0.0968	0.1437	H_o Accepted	Normal
	control	0,1161	0.1437	H_o Accepted	Normal
Postest	experiment	0,0705	0.1437	H_o Accepted	Normal
	control	0,1236	0.1437	H_o Accepted	Normal

From the results of the pretest normality test of the critical thinking skills of the experimental and control class in table 8 obtained the value of $Lo < L_{tabel}$, so Ho was accepted. This shows the pretest scores of the critical thinking skills of the students of the experimental class and the normally distributed control class. Similarly, it can be seen in table 8 for the posttest data that the value of $Lo < L_{Tabel}$ so that H0 is accepted. This shows the postest data is normally distributed.

Furthermore, a variance homogeneity test was carried out using the Fisher test. The results of the homogeneity test are shown in table 9.

Table 9 Homogeneity Test Results Pretest and Postes Critical Thinking Skills

Data	F_h	F_t	Information	**Conclusion**
Pretest	1.330	1,72	H_o Accepted	Homogen
Postest	1,360	1,72	H_o Accepted	Homogen

From table 9 for pretest data critical thinking skills, it appears Fh<Ft then Ho is accepted. This suggests both groups of data are from homogeneous populations. Similarly, the posttest also shows the value of Fh<Ft. So, it is known that both groups of data come from homogeneous populations. Furthermore, to find out the difference between the two classes, it is carried out with the T test. T test results are shown in table 10.

Table 10 T Test Results pretest data and posttest Critical Thinking Skills

Data	**t_{hitung}**	**t_{tabel}**	**Information**
Pretes	0,223	2,000	Ho Accepted
Postest	5,787.	2,000	Ho Rejected

From table 10, it can be seen from the results of the pretest that the calculation < ttabel then Ho is accepted. This shows that students have the same initial ability. Meanwhile, from the posttest data after the T test as shown in table 10, thitung > ttabel was obtained, then Ho was rejected. This shows that there is a difference in critical thinking skills between the classes given treatment and the classes that are not given treatment.

In addition to analyzing the differences in critical thinking skills between the experimental class and the control class, an analysis was also carried out on the improvement of each indicator of critical thinking skills. Indicators of critical thinking skills reviewed in this study include Elementary Clarification, Basic support, Infeering, Advanced Clarification, and Strategy and tactic. Figure 5. indicates the N-Gain value for each indicator of critical thinking skills.

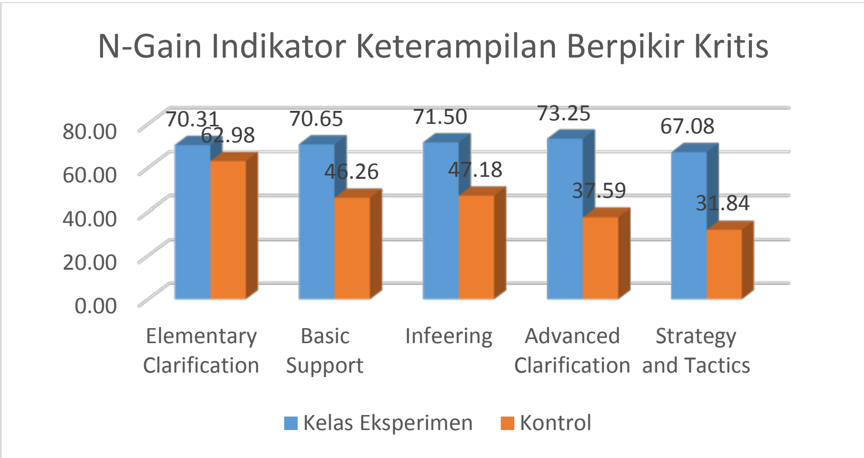


Figure 5 N-Gain critical thinking skills indicator

In figure 5, it can be seen that the critical thinking skills in the experimental class look higher when compared to the control class. The highest increase in critical thinking skills in the experimental class was found in the Advanced Clarification indicator, which was 73.25% and the control class at the Elementary Clarification level, which was 62.98%. Meanwhile, the lowest improvement in critical thinking skills in the experimental class lies in the Strategy and tactic indicators, namely 67.08% and 31.84% in the control class.

4. Student responses to learning

Based on the results of the questionnaire given to students, students' responses to PBL-STEM learning can be determined. These student responses include students' opinions regarding learning that is new to them, activeness, mastery of student concepts, critical thinking skills, students' interest in STEM areas, learning motivation, integration with other subjects and skills achieved. The percentage of responses from 38 students is seen in figure 6.

p-ISSN 2548-950X
e-ISSN 2549-7170

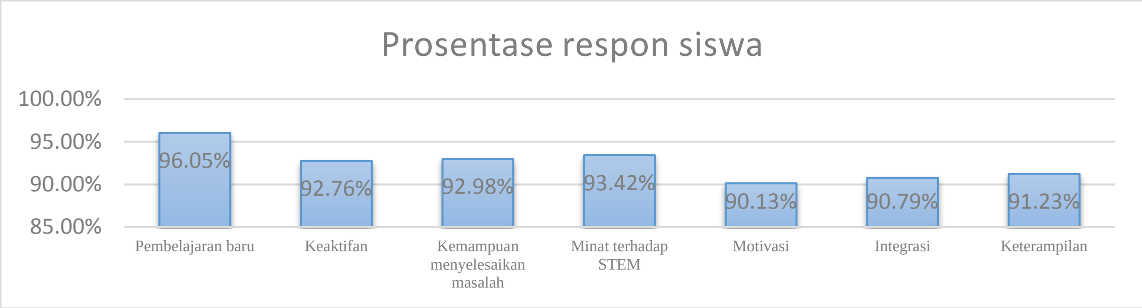


Figure 6 Percentage of student responses

From figure 6. it can be seen that the average student response shows a high score. This shows that almost all students give a positive response to the implementation of PBL-STEM learning on energy matter.

b) Discussion

1. Learning Implementation

The implementation of learning is obtained from the results of observations of teacher activities during the teaching and learning process observed by the observer. This research was conducted during 3 meetings that discussed energy themes with different problems. Table 11 shows the problems to which a solution will be sought in the energy theme.

Table 11 Problems developed in the theme of energy.

Meeting	Subtopic	Problems
1	Miscellaneous energy	What factors affect the magnitude of the energy of an object?
2	The Law of Conservation of Energy	How is the law of conservation of energy applied in everyday life?
3	Alternative energy	How to deal with energy crises?

The phases of problem-based learning with a STEM approach to its implementation are as follows:

1. Orientation about problems, in this phase many students have difficulty in formulating problems. The STEM stage, which is engagement that motivates them to get involved in learning topics through associating problems with the real world, can help students in formulating problems. For example, at the third meeting, students formulated the problem of how to overcome the energy crisis, the teacher facilitated by giving a video show about the energy crisis and the increase in fuel prices. In the show, students can see in the real world about the energy crisis so that they can formulate problems and find solutions. Students record their observations on the activity sheet. Figure 7 shows the activities in this phase.

Figure 7 View energy crisis video views

2. Organize students to research. In this phase the teacher divides the students heterogeneously. The initial problem that arises in this phase is that some students have difficulty adapting to their groupmates who are not familiar so that it will be able to hinder group performance
3. The STEM stage, namely exploration, can help overcome such problems. Because in this phase, each student is expected to share the ideas they get after making observations. Then they discussed connecting their ideas with science, technology, engineering, and mathematics. Indirectly, students will be able to adapt to the group so that they can describe and organize the tasks given by the teacher.

Figure 1 Students perform computer simulations

Figure 2 Students start creating car models/prototypes

4. Assist with independent and group investigations. In this phase students carry out experiments. In addition to getting the right information, it is also to look for explanations and solutions. These activities can be encouraged through the explanation stage in STEM, which is when students analyze data and intrepid data using the right technology. For example, at the third meeting, in search of a solution to the energy crisis, after students have organized tasks and hooked up in STEM fields, students carry out activities to design car prototypes using computer simulations from tinkercad software (technology and mathematics fields). Car prototypes designed using alternative energy such as wind energy and solar energy (technology and engineering fields)

Figure 3 test or present a model

5. Develop and present artifacts and exhibits. To encourage this phase, the STEM stage, namely elaboration, in this phase, students begin to expand their understanding of the concept by developing prototypes/models. For example, when students have simulated and designed prototypes, students start making prototypes according to their design (engineering field). Then test or present the model (Figure 10). If when tested it fails, a redesign is carried out.

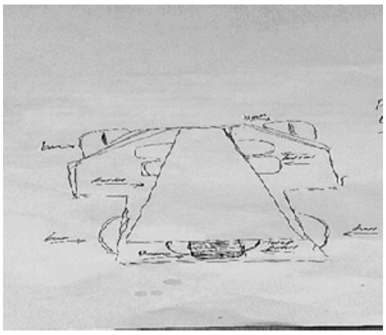


Figure 4 Initial design

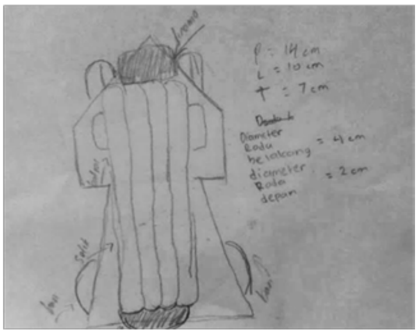
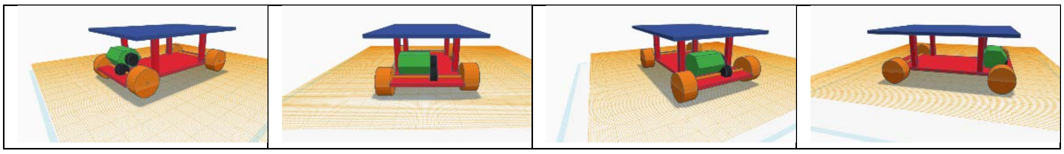


Figure 5 Redesign results

6. Analyze and evaluate the process of overcoming the problem. Students reflect on their answers or solutions to complex questions, problems, challenges, or problems.Pthere are design activities, students do preliminary design. Later in the trial, when experiencing difficulties or failures in the trial, some students redesigned. An example of the initial design and redesign that the student did is seen in figure 11. and 12. Furthermore, students use the 3D design application software to create their initial design into a 3D form as shown in figure 13.

Figure 13. The results of the design using a 3D design application that can be accessed via the internet are http://www.tinkercad.com.



p-ISSN 2548-950X
e-ISSN 2549-7170

From the results of the design that has been made, students then make prototypes of cars according to their designs. Some student-made car prototypes are shown in 14.

Figure 14. Prototypes of cars made by students

The teacher's activities in the implementation of learning based on observational data in table 1 and graph 1 show that there is an increase in implementation from meeting 1 to meeting three. The improvements are in:

a. The aspect in which the teacher helps students define and organize tasks becomes more systematic.
b. The *explore* stage is to facilitate students to be able to explore and make connections between STEM content and the process of developing solutions to problems. In its implementation, it has been more systematic, and the role of the dominating teacher is reduced

c. At the time of individual and group investigations with *the explain* stage , teachers have encouraged students to collaborate to explain concepts using previous exploratory experiences.
d. When developing and presenting artifacts and exhibits, namely at the elaborate stage, teachers have encouraged students to develop and create a model.
e. At the time of analyzing and evaluating the process of overcoming problems at the evaluation stage, teachers are already carrying out a more systematic assessment of attitudes, knowledge, and skills.

2. Mastery of Concepts

Figure 2 shows an increase in mastery of concepts in the experimental class. This can be seen from the N-Gain of the experimental class of 69.56% while the control class is 44.65%. From the results of the T test on pretest and posttest as shown in table 7, which was originally the student's initial ability was the same but after getting *treatment*, his mastery of the concept improved. This means thatthe sense of the consep of students who are given PBL- STEM learning is better than the p-p enguasaan of students who are only given the PBL model.

In the analysis of the improvement of each concept mastery indicator as shown in figure 3, the highest increase in concept mastery in the experimental class was at the C4 level of 70.96% and the control class at the C2 level of 35.83%. This happens because in PBL-STEM there is a phase of analyzing and evaluating the process of overcoming problems. In this phase there are activities intended to help students analyze and evaluate their own thought processes as well as the investigative skills and intellectual skills they use. Meanwhile, the lowest increase in concept mastery in the experimental class lies in the C5 level, namely 41.23% and 30.70% in the control class. Although it is low but still notices an improvement compared to the control class. This is because students are still not familiar with C5 questions that require making the right decisions.

Overall, the mastery of concepts in the experimental class has increased because at the *elaboration* stage in PBL-STEM in it, students are encouraged to use the new knowledge gained to expand conceptual understanding by carrying out activities that train the desired skills. This corresponds to research conducted by (Aman Yadav, Mary Lundeberg, Dipendra Subedi: 2010) which shows that students experience an increase in mastery of concepts during problem-based learning compared to traditional lecture approaches.

3. Critical thinking skills

From Figure 4, it can be seen that there was an increase in posttest and N-Gain values in the experimental class by 70.75% while the control class was 44.54%. Based on these results, it can be seen that there is an increase in critical thinking skills in the experimental class higher than the control class. The differences in the two class groups can be seen from table 10 for postest data. As for the improvement of each indicator of critical thinking skills. which includes *Elementary Clarification, Basic support, Infeering, Advanced Clarification,* and *Strategy and tactic* shown in figure 5 where it can be seen that critical thinking skills in the experimental class look higher when compared to the control class.

The highest increase in critical thinking skills in the experimental class was found in the *Advanced Clarification* indicator, which was 73.25%. This is because in PBL-STEM there is an individual and group investigation phase and *an explain* stage that encourages students to collaborate to explain concepts using previous exploratory experiences as a basis, accompanied by proof and introducing new terms or concept explanation definitions.

Meanwhile, the lowest improvement in critical thinking skills in the experimental class lies in the *Strategy and tactic* indicators, namely 67.08% and 31.84% in the control class. Although it is only 67.08% but there is an increase.

This improvement is in line with research conducted by Najihah Mustaffa, Zaleha Ismail, Zaidatun Tasir, & Mohd Nihra Haruzuan Mohamad Said: 2015, PBL plays an important role with support from ICT allowing students to improve their thinking skills.

4. Student responses to learning

Based on the results of the questionnaire given to students, students' responses to PBL-STEM learning can be determined. From figure 6 to the average student response shows a high score. The highest student response to the PBL-STEM aspect of learning is a new and fun learning for students. This is because students feel involved in the form of a group that makes students feel that they have a role in the success of the group so that students become active 92.76%and become more confident. This makes students' interest in studying science and continuing school to a higher level in science majors shown at 93.42%.

With high student interest, students' ability to solve problems increased by 92.98%. Students become more familiar with the concepts in the material studied, can think critically and become diligent in working on the tasks given by the teacher. These results are in accordance with research (Melanie 2016) that STEM learning increases knowledge and interest in a career in STEM fields, as well as increasing self-confidence.

CONCLUSION

From the results of research on the application of *problem-based learning* models with a STEM approach to improve mastery of concepts and critical thinking skills in energy matter, the following conclusions can be drawn:

1. Characteristics of PBL-STEM, the content of *science, technology, emgineering, and mathematics* in the process of finding a solution to a problem. In addition, there are STEM stages that correspond to the phases in PBL
2. Critical thinking skills in the experimental class have increased because in the PBL-STEM model there are phases that can train students to look for further explanations in finding solutions to problems so as to improve students' critical thinking skills.
3. Students respond positively to PBL-STEM because students are involved in it and learning is connected to the real world that many students encounter.

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